A Compact, Portable X-Ray System For Field Inspection

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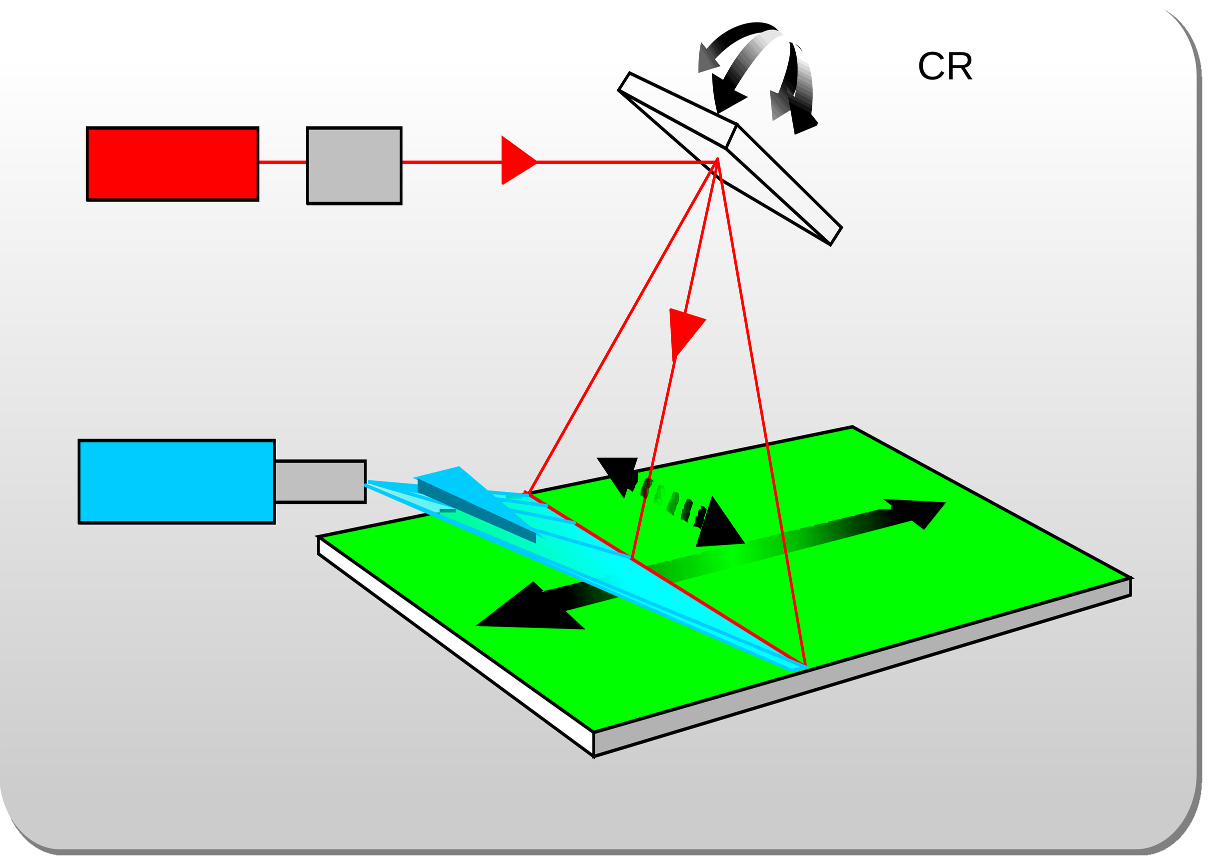
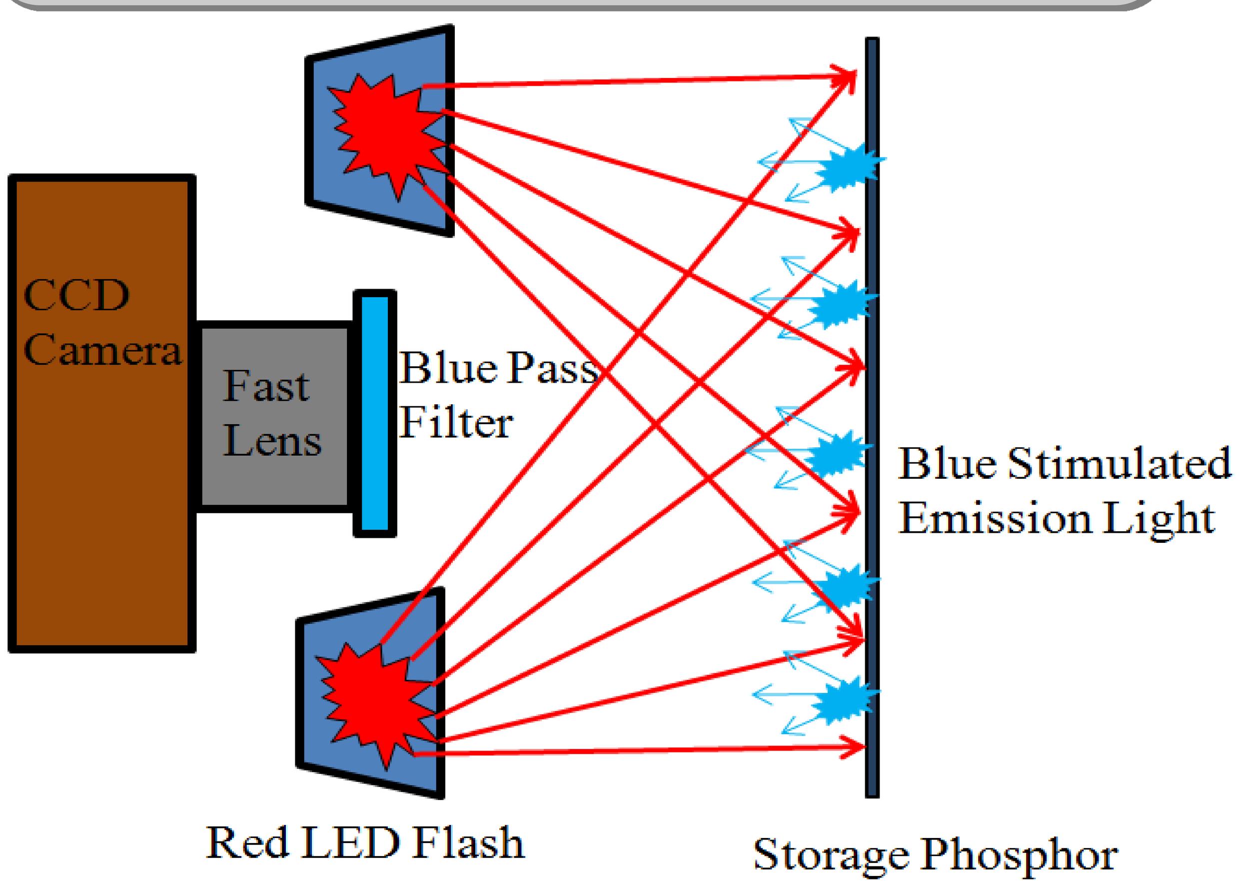
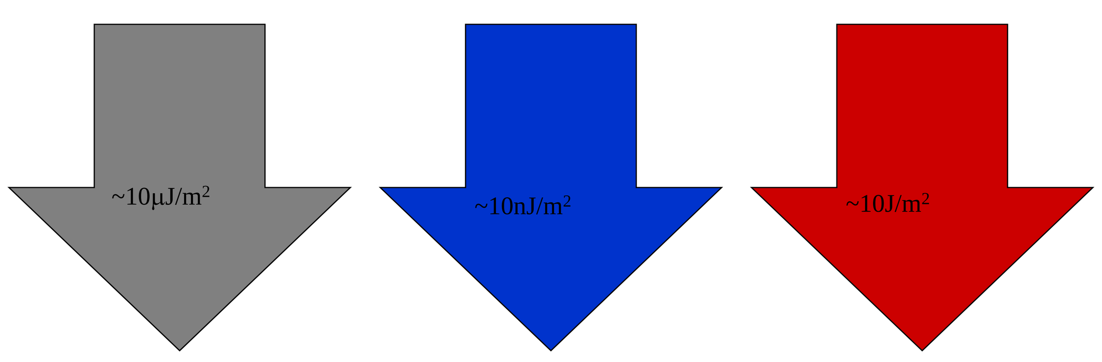
1.0 ABSTRACT - The use of x-rays for inspection is ubiquitous, and yet large, expensive, fixed facilities are presently required to accomplish this important task. We present the design of a unique, lightweight, compact, low-cost, x-ray system: MiniMAX (Miniature, Mobile, Agile, X-ray) along with typical radiographic data obtained in our trials. This system exploits the best aspects of Computed Radiography (CR) and Digital Radiography (DR) technology. In contrast to a conventional, flying-spot scanner, MiniMAX records a photostimulated emission-image from a CsBr or BaFBr:Eu storage phosphor using a single flash from a bright, red LED filtered through an extremely efficient (OD>9) dichroic filter. When combined with compact, sealed, radioisotopic x-ray sourse (eg. ^{57}Co, ^{75}Se, ^{99}Ir, or ^{60}Co), the complete system weighs less than 6 lbs and is suitable for inspecting sealed containers, facilities, and cargo. Because digital images are made immediately available, these can be readily uploaded and analyzed on a tablet computer.

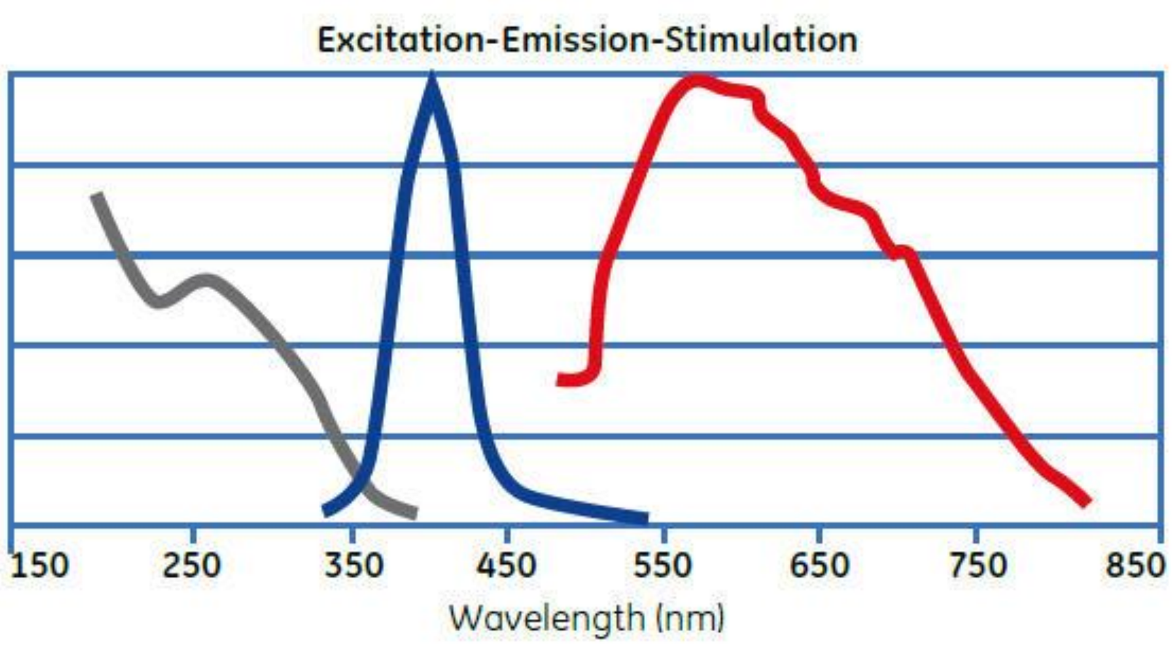
2.0 CONCEPT - Computed Radiography (CR) uses the principle of photostimulation (bottom) to record an x-ray image onto a storage phosphor material. Conventional scanners (top) use a raster-scanning laser to provide the red photostimulation light. The blue emission light is then collected on a point-wise basis using a photomultipiler tube.

With MiniMAX (middle), the entire storage phosphor is illuminated at once with a bright-red LED flash source and only the blue, emission light passes through a dichroic filter forming an image onto a CCD. The advantages of this approach are tabulated in the comparison matrix (above right).



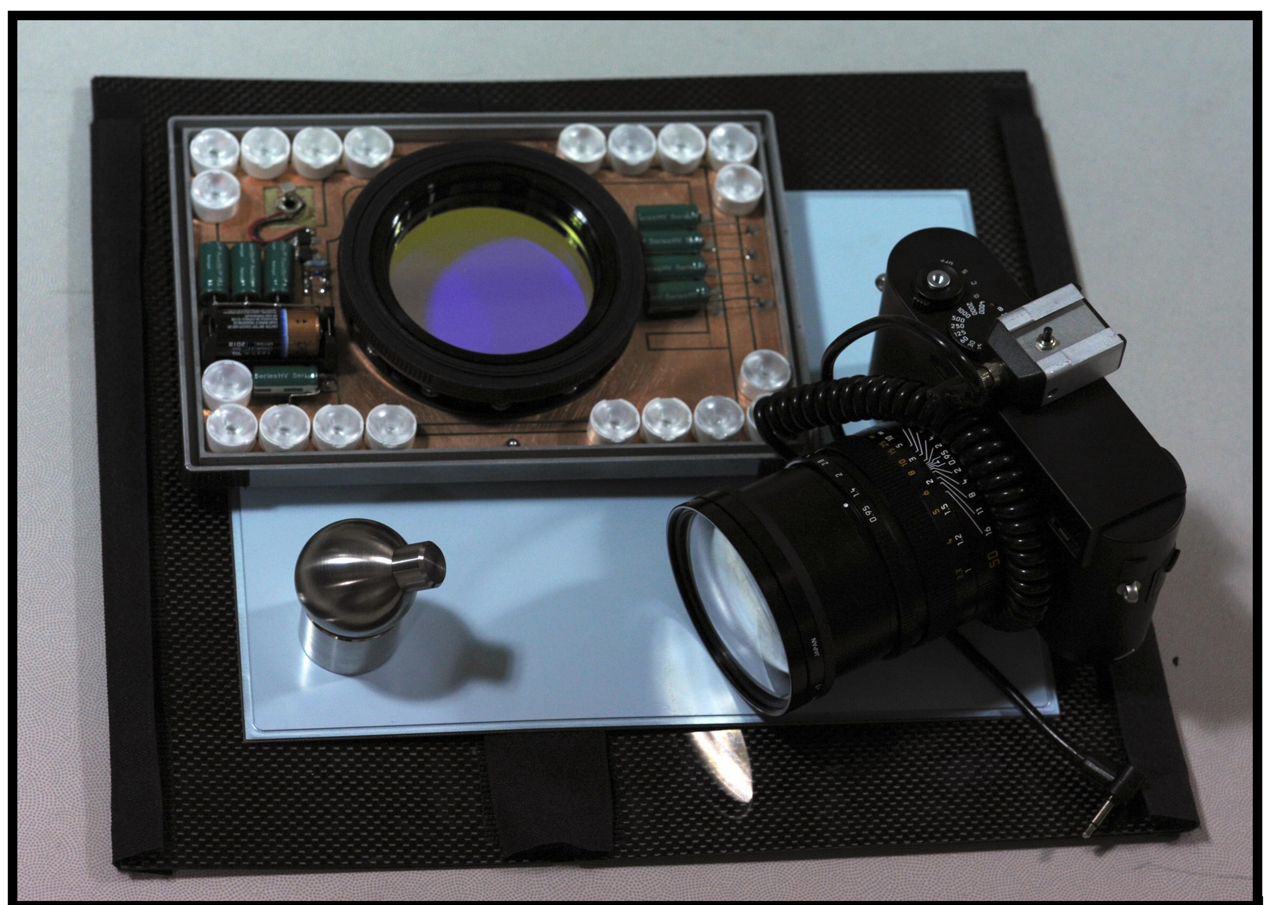






Property	Digital Radiography	Computed Radiography	Screened Film	MiniMAX
Resolution	Excellent	Good	Good	Excellent
Weight	Modest	Modest	Heavy	Low
Size	Modest	Modest	Large	Small
Cost	High	Modest	Modest	Low
Sensitivity	Excellent	Excellent	Good	Good
Rad Hard	No	Yes	N/A	Yes
Reusable	Yes	Yes	No	Yes
Dynamic Range	High	High	Good	Good
Reciprocity	Yes	No	Yes	No
Fragile	Yes	Modest	No	No

3.0 COMPARISON MATRIX with existing technologies



Complete, 6.5lb, MiniMAX portable radiography system including Leica M9 camera, Jenoptik lens, JDSU dichroic filter, LED flash, CsBr storage phosphor, and 57-Co source.

4.0 DESIGN EQUATIONS - n is the number of photoelectrons recorded per x-ray quanta absorbed, g is the phosphor conversion gain (visible photons/x-ray quanta), QE is the CCD quantum efficiency, M is the optical magnification, and $F_\#$ is the lens f-number.

The Detective Quantum Efficiency (DQE) is a summary measure of imaging performance. For a perfect imager, the detective quantum efficiency is 100%, and n >>1.

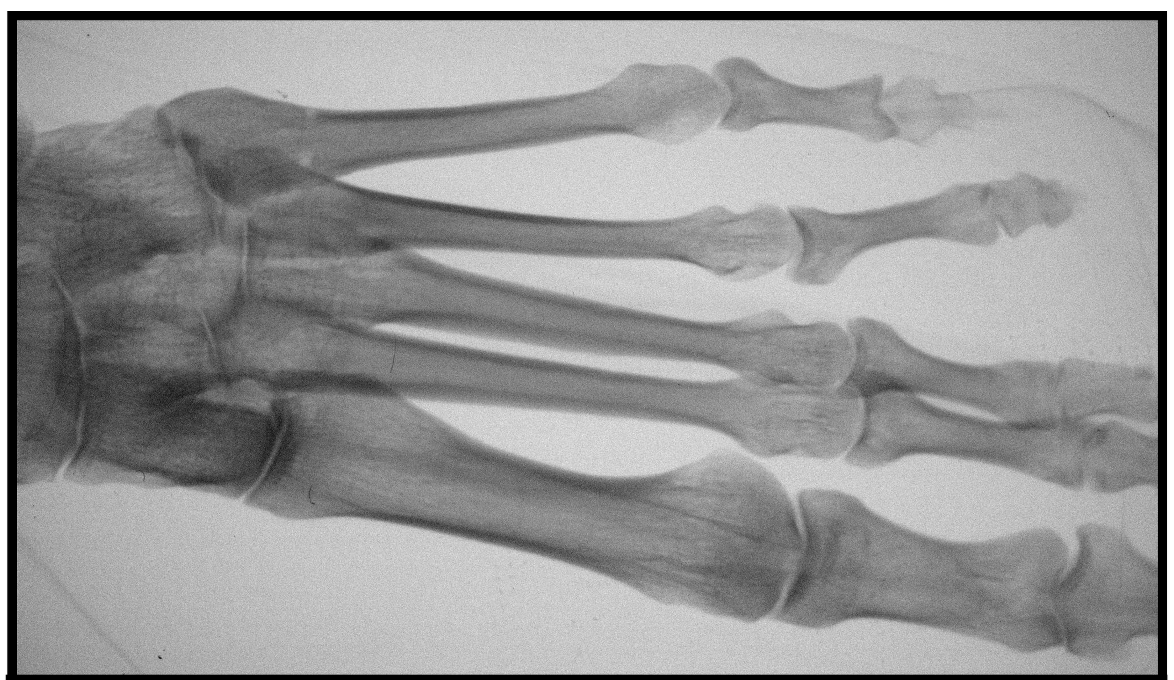
$$n = \frac{gQE_{CCD}M^2}{16F_\#^2(1+|M|)^2}$$

$$DQE \propto \frac{n}{n+1}$$

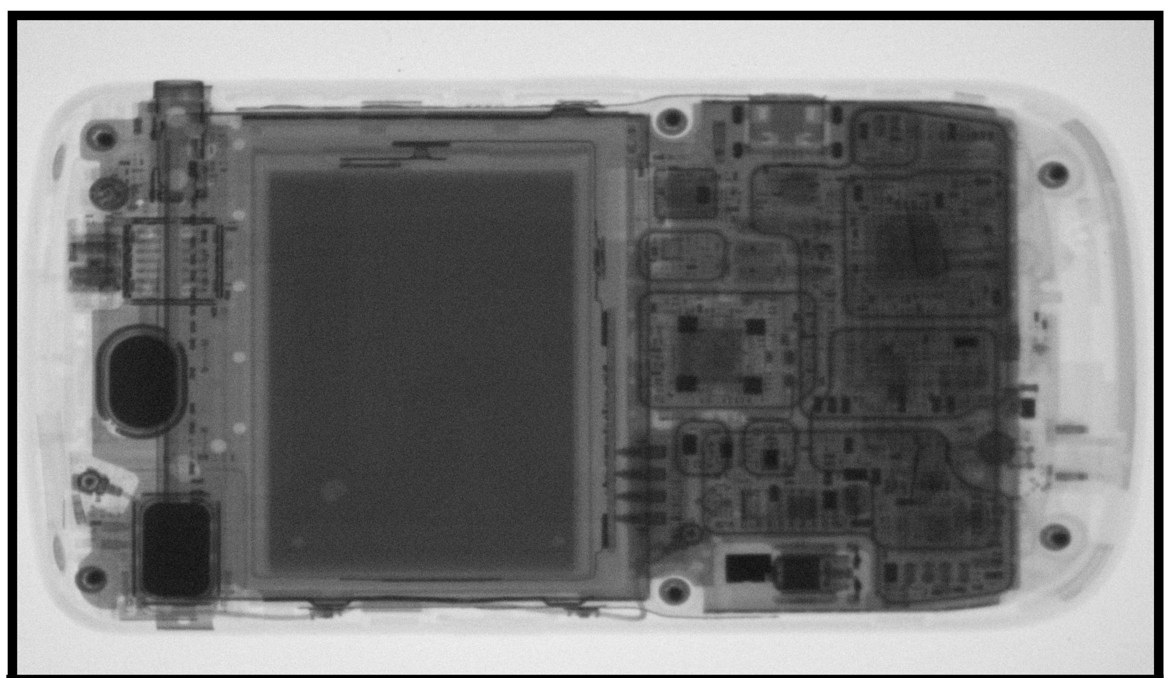
5.0 COMPACT SOURCES – We demonstrated the utility of three different, compact x-ray sources:

- The Golden XR-150 (http://www.goldenengineering.com/), conventional pulsed-power x-ray source, (below).
- A Los Alamos (www.lanl.gov), 57-Cobalt, radiosotopic source, (below left).
- The Tribogenics (http://tribogenics.com/), triboluminescent source. (below right).

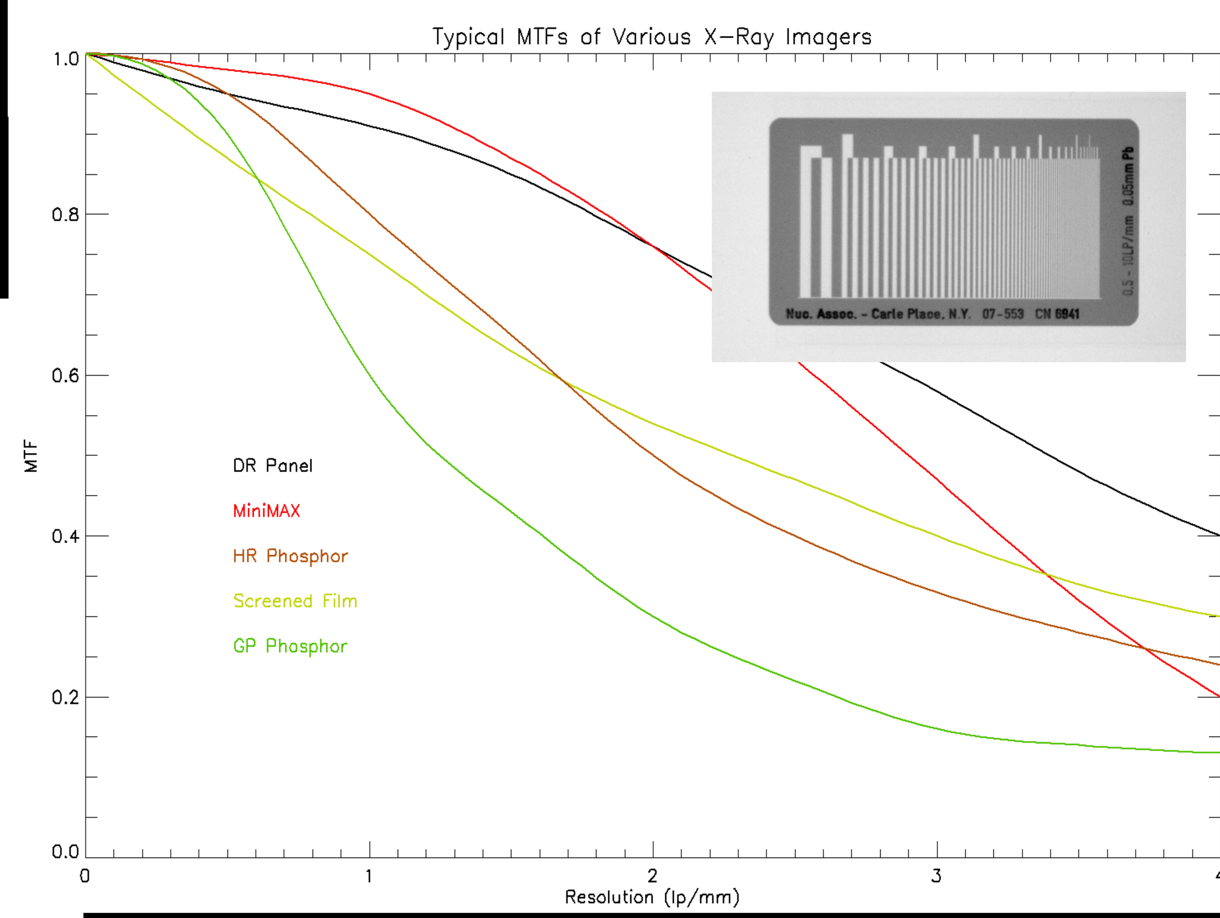
6.0 RESULTS – We x-rayed a variety of objects with pulsed and DC sources at energies from 40keV to 6MeV to demonstrate the utility of our system. Select radiographs are shown below



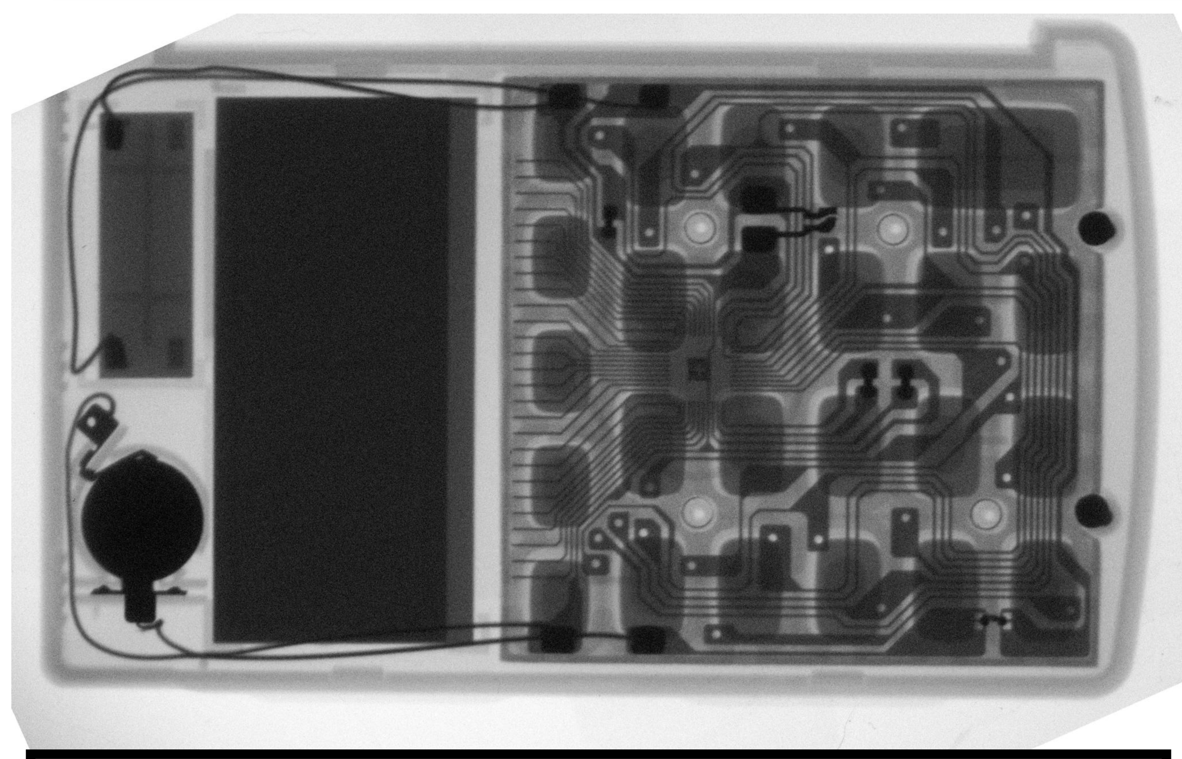
150keV radiograph of a human foot demonstrating utility in remote field hospital applications.



300keV radiograph of a cell phone receiver.



150keV Sayce penetrameter demonstrating high resolution



Triboluminescent radiograph of a hand calculator.

7.0 CONCLUSIONS - MiniMAX takes x-ray images that are as detailed or even better than conventional hospital systems. However, unlike such systems, MiniMAX is easy to use, portable, lightweight, and inexpensive. MiniMAX takes advantage of the form factor of x-ray film, the physics of computed radiography (CR), and the compact technology of digital radiography (DR) panels to implement the benefits of each in a very simple, reliable, and compact system.